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DAMS AND THE PROBLEM OF MIGRATORY FISHES

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[1]No responsibility for individual opinions expressed herein is assumed by the publishers or sponsors. The thanks of the Editor are due to Miss Margaret Storey for her aid in organizing and editing the symposium.

INTRODUCTION

By the Chairman, Francis B. Sumner,
Scripps Institution of Oceanography, La Jolla, California

For countless thousands of years, fishes of the salmon group have been pursuing their mysteriously guided migrations to and from their spawning grounds in the upper reaches of some of our rivers. And now that incorrigible marplot, man, has begun to erect huge dams to block their passage, and in other ways to interfere with their normal life history.

It may be superfluous to point out to the present audience that, unlike the Atlantic salmon, the species of Pacific salmon spawn but once. All are hatched in fresh water, often at great distances upstream, whence they pass to the ocean while still very immature, and spend one to several years in salt water. Many of them are known to wander through wide stretches of ocean, far from the mouth of any stream. Their return as sexually mature adults to spawn and die at the scene of their nativity—in the same river, and usually in the same tributary in which they were hatched, or were planted as fingerlings—now appears to be an established fact, though the theoretical implications of all this are still rather bewildering. However, it is not our present object to discuss the normal migrations of these fishes but the disturbances of these migrations through the agency of man. There are five species of Pacific salmon (*Oncorhynchus*) to be reckoned with in this connection, together with one species of the genus *Salmo*, the "steelhead trout" (*S. gairdnerii*). The chinook or king salmon (*Oncorhynchus tschawytscha*), the sockeye or red salmon (*O. nerka*), and the steelhead are the ones whose migrations have thus far been most seriously interfered with.

The recent construction of the two great dams on the Columbia River, one of which is now completed, along with the preliminary steps in the construction of another important dam on the Sacramento River in California, have been watched with keen interest and considerable apprehension by many of our citizens. Perhaps they have not been watched as closely as they should have.

The great salmon industry of the Pacific Coast is naturally concerned over the erection of structures which may seriously curtail the propagation of its stock. Those interested in less personal ways in the conservation of our wild life in general are naturally suspicious of any new large-scale interference with creatures of so much food and recreational value, and of so great scientific interest, as are these fishes. To the biologist, on the other hand, who has long been impressed with their amazing spawning migrations, the erection of these structures constitutes a vast experiment which man is unwittingly performing upon the fishes. He is curious to learn the results of this experiment, and he too, is fearsome of possible unfavorable effects upon the species concerned.

The motives for the erection of these great dams have had to do with irrigation and with power development. They were not erected in the interest of the fishes or the fisheries. Indeed, there would seem to be the probability of a vital conflict of interests here. To what extent the fishes and the fisheries have been actually affected, or are likely to be affected, we hope to learn today. Regarding some of these matters it is doubtless too early to expect final conclusions; regarding others enough is perhaps already known.

It has been the effort of the organizations which have sponsored this symposium to enlist the services of some of those men who, by experience and training, know the most about the problems to be discussed. We have fortunately been able to secure the cooperation of just such men. We shall hear from men who

ve performed some of the basic experiments from which our present knowledge of e migration of the salmon and steelhead has been derived. We shall hear from ners who have an intimate knowledge of the construction of the dams in ques-on, and have been giving close attention to the effects of these dams upon gration, so far as this is already observable.

We have with us in this audience, too, a number of persons who are well alified to discuss some of these questions, following the presentation of the rmal papers. We hope they will feel free to participate.

It seems rather superfluous for me to introduce the men who are to partic-ate in this symposium. For the most part, they are probably better known to is audience than I am. Nevertheless, some of you may lack sufficient informa-on regarding them, so I shall endeavor to supply this.

Willis H. Rich, Professor of Biology at Stanford University and Director the Department of Research of the Fish Commission of Oregon. Dr. Rich was in arge of the Division of Scientific Inquiry of the U. S. Bureau of Fisheries, 22-1926, and was Chief of the Bureau's Salmon Investigations, 1926-1930. During s service with the Bureau, he directed very extensive marking and tagging periments upon salmon.

Harlan B. Holmes was Aquatic Biologist of the U. S. Bureau of Fisheries r several years, but was later assigned to the U. S. Army Engineers. In this pacity, he was the man who planned and saw to completion the gigantic fishways the Bonneville Dam. Mr. Holmes also participated in some of the basic experi-nts upon salmon migration, in coöperation with Dr. Gilbert and Dr. Rich.

Wilbert M. Chapman was Scientific Assistant with the International Fish-ies Commission at Seattle, and is now in charge of the fisheries investigations ing made relative to the Grand Coulee Dam by the Department of Fisheries of the ate of Washington. He has carried on extensive studies of the anatomy, physiol-y and taxonomy of fishes, as well as matters more directly related to the sheries.

Harry A. Hanson has been Scientific Assistant with the International Fish-ies Commission at Seattle, later Assistant Chief of the Division of Scientific quiry of the U. S. Bureau of Fisheries. He is now chief of an investigation rty of the U. S. Bureau of Reclamation, investigating the Sacramento River lmon. In this position he is in direct charge of fisheries investigations at e Shasta Dam.

Alan C. Taft, Chief, Bureau of Fish Conservation, California Division of sh and Game, was for a number of years Aquatic Biologist of the U. S. Bureau of sheries engaged in salmon and trout studies in Alaska and California. In the urse of these studies he conducted various marking experiments on both Pacific lmon and steelhead trout.

FISHERY PROBLEMS RAISED BY THE DEVELOPMENT OF WATER RESOURCES[2]

By Willis H. Rich, Professor of Biology, Stanford University,
and Director of Research, Fish Commission of Oregon

"Those of us who are interested primarily in the problems of conservation and more particularly in the maintenance of the salmon runs of the Pacific coast of North America have, at this time, good reason to be concerned as never before over the welfare of this one of the major biological resources of the west. Until quite recently our attention has been focused chiefly upon what may be considered the normal, legitimate problems connected with the husbandry of any biological resource. By normal and legitimate I mean those problems that are inevitably associated with the extensive use of such a resource—the prevention of waste and of over-exploitation.... Now, however, we are confronted with a series of problems of an entirely different nature .... problems that have been brought into the picture by .... forces associated with the multifarious .... activities of Man, and particularly of groups of men in their struggle for dominance. These problems belong, perhaps, to the field of so-called Social Sciences; but I feel very certain that none but biologists will take any immediate interest in them and, unless some early action is taken there is not likely to be much cause for worry remaining."

These statements are quoted from a paper that I read in 1934 before the Western Society of Naturalists. The details have changed but the general statement is as true today as it was then. The two major problems with which I dealt were those connected (1) with the serious depletion of the sockeye salmon runs to the Fraser River and (2) with the engineering developments on the Columbia River that had to do with the increased utilization of this river for power, navigation and irrigation. [See map, page 214.]

At the meeting at which this paper was read a resolution was passed favoring the passage of the treaty with Canada, then pending, for the adequate protection and rehabilitation of the Fraser River salmon runs. Since then the treaty has been passed and work begun that we may hope will lead to the restoration of those unsurpassed runs that formerly entered the Fraser every fourth year.

With respect to the Columbia River developments, the only item that was definitely under way in 1934 was the Bonneville Dam, and there was no assurance then that the provisions to be made for the passage of fish past the dam would prove successful. No one could say definitely that the adult salmon on their spawning migration would successfully negotiate the fish ladders or could be successfully lifted over the dam by means of the fish locks. Nor could anyone be sure that the young fish on their seaward migration would pass down, through, or over the dam, without serious loss.

The dam was finally closed in January, 1938, and the operation of the fish ladders during the following season proved entirely satisfactory. There is some loss at the dam, no doubt, but it is apparently insignificant. It appears likely, although of this there is still no certainty, that the young fish pass down without undue loss. (Later I shall mention experiments designed to test the mortality of young fish due to the dam.) On the whole the pessimistic outlook that I saw in 1934 has been proved, at least in part, to have been unwarranted.

Much progress has been made since 1934 in the development of means to counteract the unfavorable influence on migratory anadromous fishes of such dams

[2]Contribution No. 2, Department of Research, Fish Commission of Oregon.

that at Bonneville. Considerable study and research have been given to the oblem and we now have the benefit of experience at Bonneville on which to ild. We may well be encouraged, but it would be a serious error to think that l danger is past. Even if we can assume that the Bonneville problem has been ccessfully solved we are now definitely confronted with other problems of some- at similar nature but to which, for one reason or another, the lessons learned Bonneville will not directly apply; and there is no telling how many more such oblems may arise in the course of the next few years. The Grand Coulee Dam is lf done; Shasta Dam is under way, surpassed in size only by the one at Grand ulee; there are nine or ten more dams planned for the main Columbia River be- een Bonneville and Grand Coulee in addition to the one constructed a number of ars ago at Rock Island; nearly as many more are proposed for the Snake River tween its junction with the Columbia River and Lewiston, Idaho. Still another ries of dams is planned for the Willamette River and will threaten the continu- ce of the salmon runs spawning in this stream which are of special importance sportsmen on account of the superb hook and line fishing that is available ch year during April and May in the river below the falls at Oregon City. Other milar projects that have been planned for many other of our coastal streams ght be mentioned but the list is far too long to give here. [See map, page 215.]

Each of these projected developments will present its own set of condi- ons and its own problems. Each will challenge the knowledge and ingenuity of ie fishery conservationist and, perhaps even more, will test the courage and pirit of those administrators whose duty it may be to preserve and maintain our shery resources. They will be subjected to continuous and unpleasant pressures y groups who will be interested in the development of our water resources for her purposes, regardless of the importance of the fisheries, and of the effect the fisheries that such developments may have—and, furthermore, regardless of ie need for whatever such development may produce in the way of other benefits. here will be pressure in the direction of reducing the capital and operating st of these developments by skimping on the provisions for maintaining the igratory fish resources. We shall need honest, capable and informed fishery dministrators just as much as we shall need to solve the biological and engi- eering problems connected with the protection of the migratory fish resources in ie face of the present great surge of development of our water resources.

It is the purpose of this symposium to outline the problems that have risen and the progress that has brought us to our present state of knowledge ith respect to these problems and their solution. Regardless of one's ideas as o the soundness of the policy behind the building of so many great dams, those f us who are interested in the conservation of the migratory fishes are faced ith the fact that natural spawning and rearing areas for some of the most im- ortant anadromous species are being eliminated at a rate that, if continued, ill soon completely destroy these species unless some effective remedies can be ound. This symposium will give an opportunity for an exchange of ideas that may aterially speed up the development of such remedies.

The situation has become particularly acute on the Pacific Coast during he past five or six years with the starting of a number of large developments of he "multiple use" type by the federal government. These involve, obviously, the tilization of certain other of our natural resources that are, unquestionably, f great importance and value to the community as a whole, and the tendency has een to lose sight of the important fishery resources that are almost certain to e affected by these developments. I believe that it will be futile, in the long

run, to try to stem the course of the development of these other resources, particularly those of water power and agriculture. In general these are potentially more valuable to the community as a whole than are the fishery resources, and the laws of economics will be served. Whether this is true at the present time or not, in respect of any particular stream, may be open to question, but, in the long run, I believe that this statement is true.

The sound policy would seem to be: (1) To require that due consideration be given to the maintenance of the fishery resources *at the time the other developments are being planned—not after they have been determined upon and are under way.* (2) To make every effort to develop methods that will permit the maintenance of the fishery resources under such conditions as may be imposed by the development of water power and agriculture. It seems not unreasonable to believe that general principles may eventually be developed that will be of general application and that may point the way to the development of our water resources in such a manner as to leave the supply of migratory fishes more or less intact. It is certainly true that the annual flow of most streams is sufficient to serve all purposes if the water can only be properly distributed in time and space. (3) So far as may be it seems reasonable to require that the development of water resources be retarded rather than speeded up while, at the same time, the development of methods of preserving the migratory fishes in the face of such developments be speeded up to the utmost. These developments are undoubtedly coming eventually and there are probably no more pressing problems presented to the fishery conservationist than those associated with this increased utilization of water.

Considered from a general viewpoint the situation arising from the erection of dams may be stated thus: The increased utilization of water resources, especially for irrigation and power, is modifying the environment in a number of ways so that there is grave danger that the migratory fishes will entirely disappear from many of our streams and will be greatly reduced in abundance in many others. The chief engineering structures involved are, of course, the dams and the diversions of one sort and another. But these modify the environment and otherwise affect the normal life of the fish in a number of ways. It may help to clarify our consideration of the problems to give a brief outline of the more important ways in which the environment is modified, the effect of these modifications on the fish, and the means that seem possible for overcoming the difficulties.

1. First and foremost, we have the fact that the unmodified dam itself interposes an insurmountable obstacle to the ascent of the adult fish. Somehow the adults must be gotten over, or else the entire river above the dam is lost as a spawning ground and as a rearing area for the young fish previous to their seaward migration. This has been done successfully by means of fish ladders and fish locks and even by hauling the fish around the dam in specially designed tank trucks. If provision cannot be made for passing the adult fish over the dam some substitute must be provided for the spawning and rearing areas that are lost. This may be done by transferring the adult fish to suitable streams that, for one reason or another, are not already fully populated, or by substituting a system of artificial propagation and rearing. A combination of these two methods is to be applied at the Grand Coulee Dam. Something can also be done to increase productiveness in the remaining areas by improving or opening up new spawning areas, increasing the natural food supply, and reducing predation.

It is difficult to calculate, quantitatively, the extent to which spawning

l rearing areas have already been reduced in most of our Western rivers. There little reliable information as to the original extent of these areas and of e runs of anadromous fishes that spawned in each. We do know that the salmon awning areas of the San Joaquin are practically gone. The blueback spawning eas of the Columbia River have apparently been reduced to a small fraction of eir former size—the Payette Lakes, Wallowa Lake, and the several lakes of the kima system have all been eliminated by impassable dams. The chinook spawning eas in all of the major streams of the coastal states have been reduced, but to st what extent is not definitely known. On the Columbia River the U. S. Bureau Fisheries is conducting a survey that will give, finally, some idea of what s happened.

2. The dam and attendant structures, such as power houses, impose more or ss dangerous conditions for the descent of the young fish in their seaward gration. The effectiveness of the river above the dam as a breeding area will reduced in proportion to the loss of young fish at the dam. This loss may be nimized, if not entirely prevented, by the installation of special by-passes r the downstream migrants and by screening and otherwise diverting the young sh away from areas where special hazards exist. Similarly, provisions must be de for the return to the sea of the adults of species, such as the steelhead, at survive the spawning period.

3. In the case of irrigation projects, the diversions constitute one of e most serious dangers to the survival of the young fish in their seaward mi- ation. Similar diversions for power may also be dangerous, especially with rtain types of power wheels. Screening the intakes is the only effective means combating this condition, but it may be well-nigh impossible in the case of ch an enormous pumping plant as the one to be installed at Grand Coulee—with a pacity of some 16,000 second-feet.

4. The formation of a lake-like reservoir above the dam may affect the sh in several ways. It may flood, and make unsuitable, areas that are of im- rtance in spawning and in the rearing of the young, and in the extreme case, uld completely negative whatever success may be attained in passing adult fish er the dam. Probably of more importance, however, is the effect that the intro- ction of such a reservoir into a river system may have upon the migrations of th adult and young. How will changes in current, temperature and chemical con- tions affect their movements and their survival? The effect is not confined lely to the area above the dam but may be found in changed conditions below the m. The temperature may be raised or lowered and the flow modified so as to fect the migrations or the conditions in areas where the young fish normally ve. Under certain conditions I believe that the effect of the reservoir above e dam will have a profound influence, and this should be kept constantly in nd since its effect cannot be eliminated, and thus it may determine, to a con- derable extent, the measures that can be effectively used. It is our natural ndency to consider only the unfavorable aspects of these developments, but it ould be borne in mind that, particularly in respect of this feature, the effect y be advantageous by producing more favorable conditions of temperature and ow.

5. The taking of water out of the natural channels by diversions for any rpose may so reduce the flow of the stream as to provide insufficient water on e spawning beds, insufficient area for the rearing of the young, or insuffi- ent water in the stream for the normal movements to and from the sea. In ef- ct, diversions reduce the size of the stream, and proportionally, the capacity

of the stream to support fish life. As a result of the slower current, temperature conditions may be changed—in fact, the entire ecological organization of the area may be modified, and usually that modification will be to the detriment of the native fishes.

As a representative of the Fish Commission of Oregon I shall speak briefly of our activities in this field. The Commission has been, naturally, especially concerned with the provisions for getting the fish past the Bonneville Dam in both their upward and their downward migrations. It took, a number of years ago, a very definite stand in favor of the fish ladders at a time when most of the other responsible organizations were willing to accept the fish locks as a satisfactory means for passing the adult fish over the dam. The experience of the past year showed clearly the importance of providing this more natural avenue, and the remarkable success of these ladders makes it seem probable that similar ladders might be successful at dams of almost any height that may be expected.

However, getting the adult fish up is only half the problem, as we have already seen. There is still the question as to the effect of the dam on the survival of the seaward migrants. To test this the Fish Commission of Oregon began in 1938 a marking experiment in which 100,000 young chinook salmon were marked at the Ox Bow Station on Herman Creek. These fish were marked by the removal of one or the other of the ventral fins—half with the right fin and half with the left fin. One lot, those from which the left fin had been removed, was then planted just below the dam and the other about three miles above the dam but well below the mouth of Herman Creek, in which they had been reared. Usually in such experiments two fins are clipped, which greatly reduces the chance of the experimental mark being duplicated by an accidental mutilation. Unfortunately, in 1938, the only marks involving two fins that were not already in use were so different as to raise a question as to whether this alone might not cause a difference in the survival rate.

This experiment has been repeated this year (1939) by using the adipose and the right ventral for one mark and the adipose and the left ventral for the other. The U. S. Bureau of Fisheries, under the supervision of Mr. J. A. Craig, has also, this year, performed a similar experiment at the Spring Creek Station near Underwood, Washington, some 40 miles above Bonneville. The Oregon Commission plans, furthermore, to repeat the experiment in both 1940 and 1941. The fish planted above the dam are handled as nearly as possible in exactly the same way as those planted below the dam, and the marks selected are as nearly alike as possible, so that there should be no differential mortality except such as may be referred to the fact that one lot was planted above and the other below the dam. The proportional return from the two series should, therefore, show conclusively the influence of the dam on the survival of the seaward migrants. I know of no other way in which this problem can be approached.

The question has naturally arisen as to the proper distribution of responsibility for the installation and operation of whatever structures are necessary for the protection of migratory fishes at these dams. The State of Oregon has taken a stand on this matter that I believe is sound and should go into the record of this symposium. It is well expressed in the following quotation from a letter to Secretary Ickes from Chairman Veatch of the Commission, who says in part: "It is our opinion that where dams are constructed by the federal government which interfere with the run of migratory fish, that the government should, as far as possible, remedy the damage done to fish life by the construction and operation of such facilities as may be necessary under the circumstances. We do

feel that a lump sum payment to the states involved adequately compensates such damage, for the reason that it is a continuing damage year after year, iiring continuity in the remedial measures, and it is our opinion that the ces should not be burdened with the responsibility for future operations."

Until the experimental stage is passed and we are able to lay down some nciples of fairly general application, it must be expected that the various ns provided for the preservation of our migratory fishes will be exceptionally tly. We shall be able to see later where the costs of these essentially ex- imental systems could have been reduced, but, at present, expense cannot be much considered. The excessive cost must be charged to the development of hods that may be of future use in handling, more economically, the problems t will arise as the planned developments are carried out. In general, the tes cannot afford to make these costly experiments—an additional reason why y should be in the hands of the federal government and the costs chargeable to developments involved—but it is obvious that the local interest and knowl- e of the state fishery authorities should be made use of through close and endly cooperation.

As I see it, one of the chief difficulties in the way of a satisfactory ution to the problem of dams and migratory fishes lies in the fact that there no centralized or coordinated effort possible under the present state of organization. Not only is there lack of centralized effort, but there is alry and jealousy between some of the various agencies that should be working ether. Opposed ideas are desirable, if they can be approached in the scienti- spirit and not in a provincial spirit of antagonism, and I feel sure that the t effective work cannot be done under the conditions that appear to exist in tain quarters today. The solution may lie in the direction of an effective anization of the existing agencies; it may lie in the direction of a privately owed research organization, the findings of which would carry weight enough to e them more or less effective. But I believe that, far more effective, and far e probable, would be an agency sponsored by the federal government, but so anized as to be free from all political pressure; an agency the function of ch would be to pass in review all proposals for private and public utiliza- n, development, and conservation of all natural resources. Such an organiza- n should consider all sides relative to any controversial proposal, particu- ly in cases where development of one resource adversely affects another, and vision should be made that its decisions may bear consequences. The value and fectiveness of such an organization will depend primarily upon the extent to ch it can be maintained as a non-political, unprejudiced organization, and can ll have real power to enforce its decisions.

This is particularly true from the standpoint of the conservation of mercial fisheries, because these represent a relatively small financial power. posed to the interests of the commercial fishermen are the important groups presenting agriculture and hydro-electric power, which groups, if pressure ld be effective, would far overbalance the interests of the fisheries. Many of , however, feel that the value of the fishery resources is not to be measured irely by the economic importance of the commercial fisheries, but that, as logical resources that can be preserved into an indefinite future by proper e, or can be utterly destroyed by lack of that care, they are worthy of con- deration far beyond their immediate economic value.

THE PASSAGE OF FISH AT BONNEVILLE DAM[3]

By Harlan B. Holmes, Aquatic Biologist,
United States Bureau of Fisheries

In January 1927, Congress passed an act that instructed the United States Army Engineers to make a general survey of the Columbia River for the purpose of preparing a coordinated plan for the development of the river for power, irrigation, navigation, and flood control. The plan that was developed involves a series of dams that would convert the main Columbia River into a series of deep-water pools, extending from tidewater nearly to the Canadian boundary.

By the time this study was completed, one of the dams of the series, at Rock Island, was under construction by a private power company. Grand Coulee Dam, now under construction by the United States Bureau of Reclamation, represents the farthest upstream of the series. [See maps, pages 214 and 215.]

Bonneville Dam, situated at the head of tidewater at a distance of about 140 miles from the mouth of the river, was selected as a part of the program of the Public Works Administration to be constructed by the U. S. Army Engineers. Let me emphasize the fact that this project was a part of the program of the Public Works Administration, and accordingly was a relief measure, bearing the requirement that it aid in the immediate employment of labor and circulation of capital. This condition was responsible for many of the unusual conditions that prevailed during the designing and construction of the dam.

When funds for the construction of the project became available in September, 1933, plans for the structures were represented by little more than pictorial sketches, representing the height and general type of structures to be built. Further exploration of foundation conditions was required before detailed designs of structures could be prepared. Contracts were let for excavation and construction before final details were available.

Practically the same situation prevailed with respect to the matter of fish protection. In the preliminary report referred to above, there was merely enough to indicate the presence of fishways. For the purpose of estimating cost, the fishways at the Rock Island Dam had been used as a basis of comparison. The entire task of designing fishways remained to be done after the project was authorized. Soon after work on the final design of the project was started, the U. S. Engineers solicited advice on the problems of fish protection from the fishery and game departments of the states of Oregon and Washington, and from the U. S. Bureau of Fisheries. In response to the latter request, I was assigned by the U. S. Bureau of Fisheries to take charge of a study of the problem, and to assist the U. S. Engineers in designing fishways. Mr. Henry Blood was employed as engineer to work with me.

At the same time, there was organized an unofficial committee known as the "Interstate Fish Conservation Committee", composed of members from the U. S. Bureau of Fisheries; the fishery and game departments of the states of Oregon, Washington, and Idaho; the commercial fishermen of the Columbia River; and the salmon canners of that area. The function of this committee was to offer advice in the study of the fish problems at Bonneville, and to keep the fishery interests informed of the progress being made. At the request of this committee, the fishery and game departments of the states of Oregon and Washington employed Mr. Milo C. Bell, who had spent several years in similar work for the Washington

[3]Published by permission of the Acting Commissioner of Fisheries.

rtment of Fisheries, to assist with the study. Several members of the design- staff of the U. S. Engineers took active parts in developing the plan of ways. All of the final detail designing was done by the U. S. Engineers. As a lt of the cooperative procedure that was adopted, the credit or blame, as the may be, belongs jointly to this rather composite group of workers.

Upon superficial consideration it might appear that the Bonneville fishway blem was simply one of straightforward engineering, in the application of ventional fishway practices. We soon found that such was far from the case. the task of becoming familiar with the various features of the project was small undertaking.

Picking at random from these features, we learned, for example, that the would occupy two channels of the river, separated by an island. (See Figure The only water to flow through the south channel was to be that which passed ough the hydraulic turbines, whereas, the north channel would carry all water required for power. We learned that when the project was first completed and re would be little demand for power, nearly the entire flow of the river, and ordingly, the bulk of the fish, would follow the north channel, whereas, in future, when all power units came into use, all of the water for several ths of the year would flow through the powerhouse, attracting the fish to the th channel. It accordingly became necessary to design dual fishways in the two nnels, with full capacity in each.

We learned that, in the course of the annual fluctuations in river flow m dry season to freshet, the elevation of the water surface below the dam ld vary as greatly as 30 or 40 feet. To design fishways with entrances at- ctive to fish at all such stages proved to be a major problem.

A few gray hairs were added to the heads of the staff while pondering over passage of fish during the period of construction. Each step in construction essitated reconsideration of routes of passage for the fish. Figure 2 illus- tes one of two temporary fishways that were in use during the last season of struction. Upon the basis of a partial count, it is estimated that 100,000 h passed through this fishway in a single day. This number, however, repre- ted a few days' accumulation of fish that had awaited adjustment of conditions facilitate their passage.

There also was the problem of the passage of the young fish on their way the ocean. It at first seemed that it might be necessary to attempt, at least, tremendous task of screening the turbine intakes, so as to direct the seaward grants to safer routes of passage. Before attempting this, a study was made of conditions that small fish would encounter in passing through the turbines. A ries of laboratory and field tests revealed the fact that, from the standpoint the passage of fish, hydraulic turbines differ all the way from literal sau- ge grinders to a very satisfactory route for the passage of fish. The Bonne- lle turbines, due to their great size, low pressure, slow speed, and type of sign, fortunately fall at the latter end of this range of variation, leaving ttle to worry about. Consideration of screening therefore was discontinued.

From the standpoint of the passage of fish, one of the Bonneville turbines n be visualized by considering a vertical cylinder in which a propeller similar a ship's propeller is mounted in such a way that water flowing downward, rough the cylinder, will turn the propeller. Figure 3 gives a good impression the great size of the cylindrical tube at Bonneville. Figure 4 shows the nner in place, as seen from below. The runner is 23 feet in diameter, and tates at a constant speed of 75 revolutions per minute.

Table 1. Number of fish counted through fishways at Bonneville Dam.

	Chinook Salmon	Blueback Salmon	Silver Salmon	Chum Salmon	Steelhead Trout	Shad	Suckers	Chubs	Squawfish	Lampreys[2]
1938										
May[1]	22,371	1,025	--	--	6,622	--	34,273	2,197	2,948	7,502
June	8,221	17,811	--	--	2,382	39	83,684	4,116	9,698	23,831
July	6,556	53,864	--	--	19,455	3,185	122,910	7,711	26,955	130,818
August	34,765	2,097	3,070	--	29,231	1,502	22,952	3,122	8,818	60,821
September	197,294	235	10,995	--	46,618	527	12,201	1,776	6,668	4,462
October	2,302	6	972	1,245	2,264	21	5,399	442	2,379	172
November	263	2	141	799	339	--	454	101	76	19
December	27	--	7	73	92	--	--	--	--	2
1939										
January	6	--	3	2	23	--	--	--	--	--
February	12	--	--	--	19	--	--	--	--	--
March	121	--	--	--	570	--	48	--	1	7
April	51,410	48	--	--	8,110	--	29,350	40	746	750
May	25,159	189	--	--	1,587	14	33,648	368	7,822	10,132
June	5,602	29,386	--	--	1,490	1,539	48,980	2,855	33,936	95,844
July	17,845	43,124	--	--	36,581	3,065	12,067	1,754	11,418	103,725
August	32,919	616	1,810	--	38,062	157	7,929	1,102	6,749	15,795
September	150,851	19	12,226	6	33,891	28	4,947	627	3,074	3,349
October	2,197	--	310	700	1,264	--	2,322	239	628	73
November	78	--	15	411	216	--	257	21	22	--
December	16	--	18	49	119	--	20	1	--	--

[1] May 7 to 31. Counting started May 7, 1938.
[2] Incomplete count. Partially estimated. Also many lampreys passed through hatchery [illegible]

After dispensing with the problem of the passage of fish through the rbines, there remained the question of possible injury to the fish that would ss under the spillway gates. Laboratory experiments had demonstrated that essure conditions would not be injurious, but there remained the general turbunce below the spillway. It was not possible to make much analysis of this ndition. We still should be worried about the situation, were it not for the neral observation that seaward migrants regularly pass through similar turbunt conditions at natural and artificial obstructions, such as at Celilo Falls the Columbia, and at Oregon City Falls on the Willamette.

As greater assurance that the little fish would pass the dam without jury, a complete system of by-passes was provided. In design, the by-passes are sentially the same as fish ladders for upstream migrants, except that the drop om one pool to the next below is somewhat greater. There are six such byasses: one at each end of the spillway dam, one at each shore of the south annel, one between the powerhouse and the navigation lock, and one that serves so as a trash sluice, which has entrances distributed entirely across the upream face of the powerhouse. Four of the six by-passes have their entrances jacent to screened auxiliary water intakes, which provide a large volume of ater to attract the fish to the by-pass entrances.

A great deal of time was devoted to study of the design of fishways for ne passage of the upstream migrants. Working models of the project, which were onstructed by the U. S. Engineers for their study of the structures, were utiized for extensive studies of flow conditions below the dam. An effort then was ade to design and place the fishway entrances so as to take advantage of these low conditions to direct the fish to the fishways. Figure 5 shows a small scale odel of the spillway dam with a group of federal, state, and commercial fishery epresentatives observing one of the fishway studies.

Before deciding upon the types of fishways to be installed, a thorough tudy was made of fishway practices, including those in Europe as well as in this ountry. It was found that the problem at Bonneville Dam, from the standpoint of ts magnitude, importance, and complexity, stood in a category by itself, and hat past experience could not be relied upon to indicate what might be accomlished. There arose many differences of opinion regarding the merits of various ishway features that might be employed. This lack of certainty, plus the shortge of time which would have been required for extensive experimentation, brought orcefully to attention the fact that the fishways should be looked upon as xperimental, and that they should be adapted to permit rapid adjustment while in peration, so as to make possible the selection of the most efficient operating conditions. The fishways finally installed are accordingly somewhat more elaborate than would have been required if more information had been available.

Two types of fishway structure were selected for detailed consideration. One was the pool type of fish ladder; the other was a fish lock. General designs of both types first were prepared with a view of selecting one or the other for construction at each of the several points at which fishways were required. It later was decided that both types should be constructed at each point, thus giving dual facilities, and providing greater assurance of complete success.

The fish ladders consist of a simple succession of rectangular, concrete pools, extending around the end of the dam. As water cascades down this system of pools, the fish are able to swim from one pool to the next, and make the climb without great effort. A portion of one of the fish ladders is shown in Figure 6.

The fish locks, as adapted for use at Bonneville, are essentially the same as a navigation lock. Each lock consists of a concrete chamber. Fish are attracted into the chamber by water flowing out through an entrance gate. The entrance gate then is closed and the lock chamber filled with water admitted through the bottom. An exit gate at the higher level then is opened, and the fish are permitted to swim out.

Early in the study of the problem it became evident that the design of the fishways for upstream migrants could be divided into two distinct parts, one being the structures by which the fish would climb or be carried over the dam, the other being the facilities for directing the fish to the fishway structures. The latter proved to be by far the more difficult problem. In the solution of this problem there was developed a new feature in fishway design, which we have termed a "collecting system". The basic features of a collecting system are a fishway entrance structure which provides enlarged or multiple entrances through which there flows a quantity of water greatly in excess of that which can pass through the fishway proper, this so-called "auxiliary water" being added to the system in a manner that does not distract the fish, but aids in directing them to the fishway proper. By the application of these principles, one of the fish ladders at Bonneville Dam, which has a normal width of 40 feet, and is designed to carry 200 cubic feet of water per second, is expanded at its entrance to have 41 separate entrances, each nine feet wide, making a total of 369 feet of entrance. A flow of 2,500 cubic feet of water per second is available to flow from these entrances for the purpose of attracting fish into them. This auxiliary water is added to the fishway system through 15 or more large diffusion chambers, from which it flows at a very low velocity, and mingles with the normal flow from the ladder in such a way that it does not distract the fish in their movement against the current to the lower pools of the ladder. In fact, even the human observer is unable to detect where the water is being added.

Figure 7 is a picture of this collecting system taken during construction. The passage, in which men are standing, leads to a fish ladder at the far end. The openings on the left, through which bright light is entering, are to become the entrances for fish. Rectangular holes that may be seen in the floor are for the introduction of auxiliary water from the diffusion chambers below.

The collecting system described above is in the south channel, and has its entrances distributed entirely across the downstream face of the powerhouse, vertically above the discharge from the turbines. In the north channel there are two collecting systems, one at each end of the spillway dam. Each of the three collecting systems is designed to direct the fish either to a fish ladder or to a pair of fish locks or to both in simultaneous operation.

The fishways at Bonneville Dam now have been in operation for more than a year, and their success has been thoroughly demonstrated. Continuous observations by experienced fishery workers has shown that the fish enter the fishways without hesitation, and pass rapidly to the river above the dam. It appears that each day's run passes the dam as rapidly as it reaches that point. Judgment of success is not based entirely upon general observations. To obtain more dependable information and to furnish data much needed in fisheries administration, a complete count is made of the number of fish passing through the fishways. Skilled observers tally each fish according to its species as it passes through gates in barriers placed across the upper end of each fishway. The gates are open only when an observer is in attendance. Table 1 gives the counts of the principal species counted during the first 13 months of operation. [Table extended through 1939 since submission of MS.—Ed.]

Figure 1. Aerial view of Bonneville Dam taken February 16, 1938, soon after construction was completed, but before the water level above the dam had been raised to its full height or the powerhouse was in operation. (Courtesy Air Corps, U. S. Army.)

Figure 2. Temporary fishway at north end of Bonneville spillway. (Courtesy Engineer Corps, U. S. Army.)

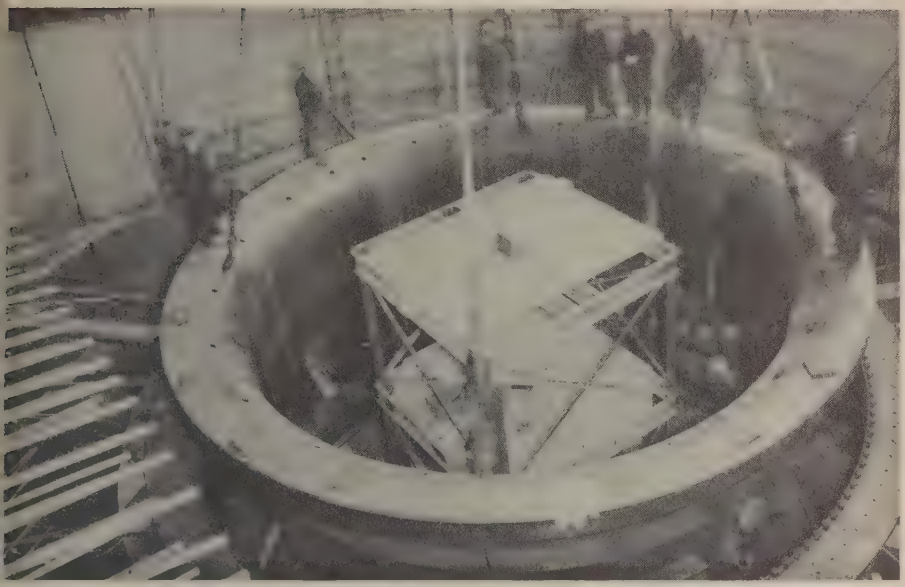


Figure 3. Steel throat of draft tube of a main unit turbine at Bonneville Dam, eing lowered into position. (Courtesy Engineer Corps, U. S. Army.)

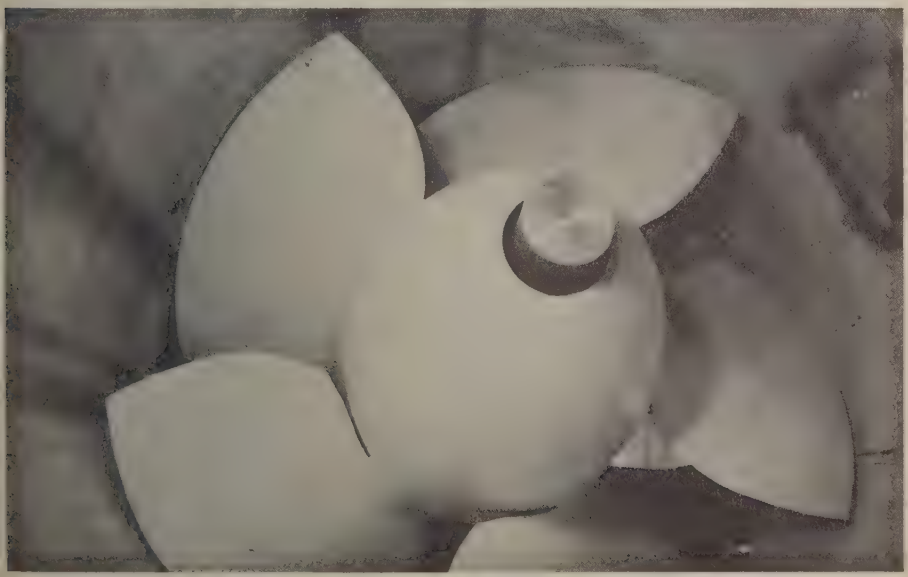


Figure 4. Main unit turbine at Bonneville Dam, looking upward from draft tube t runner in position. (Courtesy Engineer Corps, U. S. Army.)

Figure 5. Working model of Bonneville spillway dam, being used for fishway observations. (Courtesy Engineer Corps, U. S. Army.)

Figure 6. Bradford Island fish ladder at Bonneville Dam. (Courtesy Engineer Corps, U. S. Army.)

Figure 7. Fishway collecting system across downstream face of powerhouse—under construction. (Courtesy Engineer Corps, U. S. Army.)

FISH PROBLEMS CONNECTED WITH GRAND COULEE DAM

By Wilbert McLeod Chapman, Department of Fisheries, State of Washington

One hundred forty-two miles downstream from the Canadian border, the Grand lee Dam is being built across the Columbia River. [See map, page 214.] From dam, the Columbia extends north and east through Washington and British Co- bia for 603 miles to its source in Columbia Lake. Between the dam and Columbia e there are 537 miles of tributaries open to fish migration. In this 1,140 es of main stream and tributary, the spring chinook salmon, the Columbia River keye (or blueback) salmon, and the steelhead trout have ascended yearly to wn since time immemorial. In this vast area, the young salmon and trout have ched and fed during their period of fresh-water growth. This they will never again by their own initiative. Today Grand Coulee Dam has been completed to a ght insurmountable to fish.

The runs of fish involved are too valuable to be abandoned. It would take $11,000,000 investment yielding 4% annually without any depreciation to re- ce to the citizens of the states of Washington and Oregon the annual yield now eived from the fish runs affected by the Grand Coulee Dam. Their preservation brought forth a number of very difficult and complex biological and engineer- problems. It is the purpose of this talk to discuss these problems.

The first solution which would be logically considered would be to lift adult fish over the dam by means of ladders or elevators, and to allow them such means to continue upstream to their normal spawning grounds. The improve- t of fish ladders in recent years has made this feasible and successful on h large dams as Bonneville and Rock Island on the Columbia River. Grand Coulee , however, has certain constructional peculiarities which have to be consid- ed.

The elevation of the crest of the dam will be about 350 feet above the n normal river level. While difficult, it is not impossible that fish could be ised 350 feet by means of ladders or lifts. In this case, the main task would to attract the fish into the ladders. The construction of a collecting system ong the face of the dam which would operate efficiently was found to be, if not possible, at least impractical. The spillway of the dam will be 1,800 feet ng. In the spring the flow of water over this crest will be tremendous. On the sis of past years' records the peak will reach between 200,000 and 650,000 cu. t. per second. The proportionately small volume of water which could be used in e ladders would have to compete with the agitation of this 1,800-ft.-long, 0-ft.-high spill for attracting the fish. During the peak of the salmon runs n June, July, and August), occurs the maximum runoff. The greatest difficul- es, however, in constructing an efficient collecting system were not only the rge seasonal fluctuations of the tailwater levels, but also the rapid fluctu- ions of shorter duration. It is not impossible that the tailwater would be bject to maximum drops of as much as 10 or 15 feet vertically within a few nutes' time with large variations or complete cutting off of the load for the nerators. Those of you who have had experience with fish ladders will realize e difficulties of regulation which such conditions would bring about.

On the basis of the cost of similar structures at Bonneville and Rock land dams, it was found that the construction of such a system of ladders and proaches would cost at least $2,000,000, with the very good chance that they uld not work. Therefore this approach to the problem was abandoned.

One hundred twenty miles downstream is the Rock Island Dam, located near the geographic center of Washington. On this dam there are three ladders which operate with satisfactory efficiency and through which all fish coming from the sea must pass to reach Grand Coulee Dam. Between the two dams there is no place where the fish could be trapped. The Columbia is too big and subject to too large fluctuations in flow (25,000 c.f.s. to 750,000 c.f.s. at Rock Island) to consider racking. Investigations showed, however, that it would be possible and practical from an economic viewpoint to trap the adult fish in the ladders at the Rock Island Dam and transport them to a place above Grand Coulee Dam, so that they could again take to their natural spawning grounds.

The question now became, could the young downstream migrants safely get back down over Grand Coulee Dam on their trip to the sea? It was found that the chinook migrated downstream more or less throughout the spring, summer, and fall, but that there were two main peaks to the migration. One peak was in the fall, and consisted of the young hatched out that spring. The other was in the spring, and consisted of the young hatched out the preceding spring. The young steelhead migrated nearly entirely in the spring, after having spent two winters in fresh water. The blueback also migrated in the spring, part of them after spending one winter in the lake, and the rest after spending two. The size of the fish at migration varied with the species and age from two to seven and a half inches in length. There would be three main sources of danger to the young fish:

1. In the spring, when the river is rising, ten pumping plants will pump a total of 18,000 c.f.s. of water from the lake beyond the dam up into the Grand Coulee for the irrigation part of the development. This is a stream approximately the size of the Skagit River. It will not be feasible to screen the intakes of these pumps. The pumping season will coincide with the period of greatest migration of the young fish. Inevitably, large numbers would be pumped into the irrigation development and perish.

2. There will not be a spill over the dam the year round. The period of spill will vary widely from year to year with the fluctuating run-off period of the river and the power and irrigation load. In some years, at least, there will be no spill from September 1 to the latter part of April or perhaps May, coinciding with both the spring and fall migrations of the young fish. In the spring this would hold up the young fish, concentrating them behind the dam so as to increase the number taken by the irrigation pumps and predatory fish. At the beginning of the spill season, a large volume of water would flow over the 1,800-foot-long crest of the dam in a thin sheet. When the spring spill started, there would be a time at first when the sheet of water flowing over the crest would be so thin that the concentrated young fish population going over the dam would probably be all or mostly all killed by the 400-foot slide down the concrete face of the dam. The fall cessation of the spill would hold up the young fish, until the following spring, behind the dam, where there would be a minimum of food for their support, as well as a maximum of predatory activity.

3. Perhaps the greatest danger would be in the "bucket". At the base of the dam a lip is being built which has the specific purpose of dissipating the tremendous energy of the falling water. In this "bucket" the velocity of the water will diminish from about 80 or 90 feet per second to about 40 feet per second in a short distance. There will consequently be an area of extremely violent disturbance through which the fish would have to pass. Experiments at the Fort Collins scale model of the dam showed that small objects, such as the young fish, would go around and around through this area of boil before escaping down-

eam. The fish would therefore be subjected for a varying length of time to the shment of the twisting, churning mass of water. It is very probable that the ority of young fish would perish. In this instance, as in so many other phases the investigations, the crucial point of whether the young fish could survive trip through the "bucket" could not be tested experimentally until the dam completed. If there were adverse results it would then be too late to apply knowledge gained.

Because of these several obstacles both to taking the adult fish over the and returning the young fish over the dam on their downstream migration, all e of placing the adults above the dam to spawn naturally was abandoned until a time as experiments could be conducted on the completed structure.

Abandonment of the 1,100 miles of stream above Coulee Dam for natural reduction left one alternative—artificial reproduction. The logical place for hatchery would be at or near Grand Coulee Dam. A search was made for such a ation. In the rugged semi-arid country in the vicinity of the dam there was nd no adequate source of water except the main river.

The main Columbia River in Eastern Washington is a moderately warm stream ing the summer months. Its temperature usually reaches 65° F. after the spring -off late in June, and hovers between 65° F. and 70° F. throughout July and t of August. It was observed that the spring and summer chinook in a state of ure did not linger in the main river but ascended directly to the head waters the tributaries where they would lie in deep, cool pools until they ripened. blueback also proceeded directly upstream to lakes in which there was a rmocline and, therefore, cool water available.

The adult fish, when they arrive at the dam, are far from ready to spawn. nook arriving in May would not spawn until late in August. Blueback arriving July would not spawn until late September or October. Steelhead arriving in fall would not spawn until the following spring. This necessitated holding adult fish in concentration for a long period. The State Department of Fisheries had been combating similar circumstances at the Lewis River Dam in the er Columbia. There holding ponds using water from the river below the dam had n constructed in which to maintain the adult fish during the ripening period. ey were not successful with the spring chinook because of a steady and large tality during the holding period. The temperature in the holding ponds exeded 60° F. during the summer season. New holding ponds were constructed on gar Creek above the dam in which the summer temperature did not reach as high 50° F. The success of the new ponds was remarkable.

To determine whether or not a similar situation would have to be met on e Upper Columbia, an experimental holding pond was built at Rock Island Dam, ing water from the main Columbia. One hundred sixty-nine chinook, blueback, d steelhead adults were placed in the pond. Sixty-five (39%) of all the fish ed before spawning time.

It was obvious from the results of this experiment and the experiences at e Lewis River Dam that the adult salmon could not be held to ripen in the warm ter of the main Columbia. As noted above, the only source of water available at and Coulee Dam was the main river. It was found that the artificial cooling of e quantity of water needed would be too costly to consider. The nearest place Grand Coulee where deep, cool pools were available, or where cold water was ailable was in the upper Methow River, a distance of more than 100 miles over or roads. Recalling the difficulty of constructing a collecting system at the se of Grand Coulee Dam and finding a lack of adequate and suitable water supply

reasonably close by, all plans for caring for the fish at or near the dam were abandoned.

The next place downstream where the adult fish could be collected feasibly was Rock Island Dam. At that dam all fish proceeding upstream had to pass through one of three ladders. They could be trapped and loaded into trucks economically. A search was made for a hatchery site with an adequate supply of cool water. The nearest was Icicle Creek, a stream tributary to the Wenatchee at Leavenworth. In its lower reaches this stream flows through several large deep pools which were used by chinook as ripening places. It was found that the temperature of the water seldom exceeded 60° F. in the hottest part of the summer. In the summer of 1937 several hundred fish were hauled there from Rock Island, and held until spawning time. The outcome of this experimental holding showed the pools to be singularly well adapted for holding adult salmon. The mortality of the fish was slight, and their condition at spawning time was good.

It was originally planned that the fish would be hauled from Rock Island to the mouth of the Wenatchee River (a distance of 16 miles). The river would be racked at the mouth and the fish could ascend to Leavenworth under their own power. This was tried in 1937. Unfortunately the fish refused to go upstream. It, therefore, became necessary to haul them all the way to Leavenworth, a distance of 42 miles from Rock Island.

Thus we arrived at artificial propagation as the best means for preserving these runs of fish, and found that Icicle Creek on the Wenatchee River was the best available site for the hatchery and holding ponds.

Unfortunately, a direct corollary of taking the fish at Rock Island Dam was that all of the fish going into the tributaries between Rock Island and Grand Coulee must be handled with the fish normally going above Grand Coulee Dam, for the simple reason that it is impossible to tell them apart at Rock Island.

Since the area of river above Grand Coulee Dam had to be abandoned as a rearing area as well as spawning area, the next step was to find what to do with the young fish as they came from the hatchery. The following plan was finally evolved:

Four tributaries of considerable size enter the Columbia between Rock Island and Grand Coulee. These are the Wenatchee, Entiat, Methow, and Okanogan rivers. While it was known that these rivers formerly supported large runs of salmon and steelhead they, at present, maintain very small runs in proportion to their potentialities. It was determined then that the upper Columbia River runs should be transplanted to these lower tributaries where there was at present room for them. The means were to be as follows:

All of the adult fish were to be hauled to Icicle Creek where they would be held pending the ripening of the sexual products. All the eggs were to be taken at the Wenatchee hatchery, which would be the central plant and held until they were eyed out and could be transported. Three more hatcheries were to be built, one each on the Entiat, Methow, and Okanogan rivers. Upon eyeing out, the eggs were to be distributed among these four hatcheries where they would be hatched, reared, and released into the respective tributaries. It is planned that this policy will be followed for six years (one complete cycle for the oldest chinooks). At that time it is hoped that the returning adults will come back to the stream in which they were released as young fish. In other words, we will test on a large scale whether the strong homing tendency of salmon is due to environment or to heredity. There is considerable evidence that it is governed by environmental factors. If so, the plan will work. In that case, the transporta-

on of adults from Rock Island Dam to Icicle Creek can cease. And such fish as is desired to subject to artificial propagation can be taken by racking the spective tributaries at or near the hatchery on each stream. If the fish fail respond as desired to this feature of the plan, the original plan of transportion from Rock Island to Leavenworth will have to be followed indefinitely. the fish do return satisfactorily to the tributaries in which they were liberated there will be a considerable saving in money.

This plan has been adopted after a thorough consideration of several ternatives, not because it was an ideal method, but because with the limited formation available it appeared to have the most likelihood of success. Several ints bearing on the success of the operation yet remain to be determined. Among ese are the following:

It is known that the adult fish can be transported by truck from Rock sland Dam to Leavenworth and held until spawning time in the pools of lower icle Creek without undue mortality. It is not known, however, what the effect f this handling and holding will be upon the ripening sexual products. It is ntirely conceivable that the mortality among the eggs will be increased to such degree that the additional rearing facilities being provided will prove useless.

	1934	1935	1936	1937	1938	1939
hinook salmon	7,099	16,160	7,283	5,522	5,795	11,206
lueback salmon	2,227	14,012	16,516	15,091	17,095	19,591
ilver salmon	69	10	--	58	78	13
teelhead trout	580	5,213	2,333	2,329	2,399	5,427
hubs	4,826	6,597	12,963	5,811	3,486	133
hiners	1,799	2,269	1,989	468	719	--
squawfish	3,089	1,748	6,287	5,522	1,174	1,771
arp	610	39	127	199	543	2
uckers	4,122	15,987	24,732	16,678	15,075	3,389
hitefish	4,148	1,970	12	140	99	163
ampreys	9,368	11,729	903	556	674	25
otal salmonids	9,975	35,395	26,132	23,000	25,367	36,237
otal other fish	27,962	40,339	47,013	29,374	21,770	5,483

Table 2. Counts of fishes at Rock Island Dam, 1934-1939. Of the 1939 counts, urnished by J. A. Craig, U. S. B. F., the low "scrapfish" counts reflect results f by-passing these fishes to avoid hauling them with the salmonids.

It is known that sockeye (or blueback) runs now inhabit the Wenatchee and Okanogan rivers. It is not known, however, whether Lake Wenatchee and the Okanogan lakes will provide sufficient space and food for the production of nine times the number of fish of this species now produced in this area. Will the physiological inheritance of young fish which would normally have appeared in the high tributaries of interior British Columbia be similar enough to that of young fish which would normally have been produced in the Wenatchee and Methow rivers to permit the various stocks to be treated in a uniform manner with adequate survival rates? Will the sudden great increase of salmonid fishes in these four lower tributaries upset the ecological relationships in these streams to the point where there will be insufficient food to go around and predation may become a limiting factor?

The upper river runs have been subjected to a hard blow already this year. Because of considerations which I do not wish to go into at this time, the U. S. Bureau of Reclamation failed to provide the facilities requested in time for use in 1939. Grand Coulee Dam was completed to a height already sufficient to stop fish. Therefore, this year's runs have necessarily had to be cared for in a makeshift manner. The adult fish are being transported from Rock Island to the Wenatchee, Entiat, Methow, and Okanogan rivers, where they will be liberated to spawn naturally. There will undoubtedly be considerable losses, and this year's cycle may be permanently injured.

The picture is not necessarily as black as these factors would indicate. It is possible that with careful administration of the project the runs can be maintained at their present size or even increased. The means for accomplishing this are the facilities provided for rearing the young fish to a size approaching the migratory stage. One hundred forty-six rearing ponds are being provided. It is planned that all of the fish will be reared for a period of two and a half to three months. All that can be held in this number of ponds will be reared until late fall before liberation. It is hoped that the lessened mortality during this period of the fishes' lives over what would take place in the natural state will counteract the possible increased mortality rates at other points in the plan.

PRELIMINARY REPORT ON AN INVESTIGATION TO DETERMINE POSSIBLE METHODS OF SALVAGING THE SACRAMENTO RIVER SALMON AND STEELHEAD TROUT AT SHASTA DAM[4]

By Harry A. Hanson, U.S. Bureau of Reclamation

The following preliminary report is based upon an investigation undertaken he Bureau of Reclamation, United States Department of the Interior, in 1938, tudy the salmon runs which will be blocked by Shasta Dam, and to determine ible means of salvaging them. The investigation, which still is being carried is under the supervision of the Bureau of Fisheries, United States Department the Interior. The California Division of Fish and Game is cooperating on ious phases of the problem.

Shasta Dam and Power Plant are being constructed by the federal government he upper Sacramento River in Northern California as principal features of the ral Valley Project. [See map, page 215.] It is to be a multiple-purpose dam navigation improvement, flood control, supplemental irrigation, salinity con-., and electric power generation. This dam will be approximately 560 feet high will cut off all salmon spawning areas above it in the Sacramento, Pit, and loud rivers and their tributaries. [See map, page 203.]

For the following two reasons, fish ladders or fish lifts over the dam ld not prove to be either a practical or economically sound answer to the blem:

(1) Fish ladders have not proved successful to heights of over seventy t, as shown by past experience, and a fish ladder capable of allowing fish to s to a height of over 500 feet, coupled with seasonal fluctuations in the face level of the reservoir itself of over 200 feet, would involve both costly hazardous design and construction not in line with past experience.

(2) If adult salmon and steelhead were successfully elevated over the dam ladders or lifts or actually trapped and carried past the dam in trucks, there ld still be the problem of getting their young through the reservoir on their ration to the sea. During much of the period of downstream migration there l be no spill over the dam. Consequently the downstream migrants would have to s through the turbines, through needle valves near the same level, or through river outlets below the crest of the dam. Any of these routes would probably ve fatal to small salmon as shown by past experimental work. If a fish ladder e installed, there still would be the problem of attracting the small fish to entrance.

Since any scheme to pass fish over Shasta Dam would be costly and of btful success, the alternative presented is the collection of the fish below dam, and either taking their eggs artificially and hatching them, or trans-ring the adults to other waters, or a combination of both.

From the time of the establishment of the first salmon cannery on the ific Coast by Hume Brothers and Hapgood near Sacramento in 1864, commercial mon fishing has been carried on intensively in the Sacramento and San Joaquin ers, and in the ocean off shore. It has played a large part in depleting the s which annually surged up the rivers, but what is perhaps more serious, is loss of spawning grounds blocked by dams. Mr. G. H. Clark, of the California ision of Fish and Game, estimated in 1929 that 80 per cent of the spawning unds of the Sacramento salmon had been destroyed by various activities of man.

The Sacramento-San Joaquin salmon industry, although in a very much de-

[4] Published with the permission of the Commissioner of Reclamation. Originally given under the title: The Sacramento River Salmon Salvage Problem.

pleted state, in 1938 produced 1,650,000 pounds of king salmon, for which fishermen received an average of 5½ cents per pound, or approximately $90,750 net. This amount represents a 4 per cent return on a capital stock investment of approximately $2,250,000. These figures do not take into consideration gross values returned to commission merchants, retail merchants, supply and boat dealers, who perhaps shared equally with the fishermen in profits from the fishery.

The ocean-trolling catch off the California coast for 1938 amounted to approximately 1,550,000 pounds. It is not known what proportion of salmon taken in the ocean fishery are fish hatched in the Sacramento River, but there is evidence which indicates a large percentage of the catch is produced in this river.

The total catch of salmon for the past ten years by commercial fishermen in the ocean off San Francisco and Monterey bays and in the river amounted to approximately 26,000,000 pounds. The value of the catch in prices paid to fishermen during the period was over $1,750,000 net.

Counts of fish passing up the Sacramento River at the Anderson-Cottonwood Irrigation Dam at Redding have been conducted during the fall migration of salmon in 1937 and 1938. The count in 1937 was conducted by the California Division of Fish and Game. Observations were commenced on August 7 and terminated with the dismantling of the dam on October 16. The total count during the period of observation was 5,280 fish. Many salmon had gone upstream before the count was started and many more after the dam was lowered. It was estimated that a minimum of 15,000 salmon represented the 1937 escapement past that point.

In 1938 the count was made by the Bureau of Reclamation fisheries investigators at the same place as in 1937. Counting began on September 2 and continued until the dam was dismantled on October 25. Thereafter and until November 3, fish were counted on each end of the dam as they leaped over the flash boards during the dismantling process. This permitted a longer period to observe and count than was possible in 1937. By November 3, the last of the flash boards had been removed from the dam and the fish could swim freely upstream without being seen by an observer on the bank. It was believed, however, from observations at the site, and from the numbers of salmon entering fish traps at the two federal hatcheries on Battle and Mill creeks below, that the peak of the run had passed some days before. The total count during the period of observation was 13,885. It was estimated that a minimum of 19,385 salmon made up the escapement past Redding in 1938.

The 1939 count of spring run salmon was begun on April 17, and by August 31, 5,786 adult salmon had been observed passing through the counting weir in the Anderson-Cottonwood Dam. The total 1939 count was 21,831. [See graph, page 204.]

In addition, there is probably a winter or a very early spring run which goes upstream while the dam at Redding is dismantled, and which, consequently, cannot be counted. These salmon were seen spawning in the upper McCloud River and several spent fish were collected in June (1939). The fact that these fish had spawned successfully is demonstrated by subsequent collections of eyed eggs, fry, and fingerlings. These fish evidently do not belong to the spring run since the latter are very "green", and according to the Baird Hatchery records, do not ripen until September.

It will be evident from the above figures that the total number of fish, including both fall and spring runs, that must be handled in the salvage operations at Shasta Dam, will probably be upwards of 25,000.

It is necessary to know the average number of eggs produced by each female salmon, as well as the number of females passing Shasta Dam site, in order to determine the extent of salvage operations in relation to artificial propagation. The average number of eggs per female salmon was obtained in two ways. First, by

ct count, and second, by calculating the number from hatchery records over a od of years.

In 1923, McGregor counted eggs from 50 females taken in Suisun Bay, and ined numbers varying between 4,795 and 11,012, "a range of 6,217, with a mean e of 7,422".

In 1938, the Bureau of Reclamation fishery survey party made direct counts ggs in one (the right) ovary from each of three immature female salmon from le Creek, and found 3,905, 4,785, and 3,340 eggs from each, respectively. If e figures are multiplied by two to allow for the eggs in the left ovary in case, the resultant counts are 7,810, 9,570, and 6,680, respectively. The age for the three is 8,020. McGregor found that neither ovary consistently eeds the other in the number of ova.

The second method of arriving at an average number is by dividing the al number of eggs procured at the Battle Creek Hatchery by the number of ale salmon which produced them. The number of eggs taken at the hatchery for years 1926 to 1938 averaged 7,191 per female.

The records of the Mill Creek Hatchery in 1930 gave an average of 7,019 gs per fish.

Because of the small number of fish in the sample counted in 1938 by the rey crew, the resultant average of 8,020 is not considered dependable, but the seness of agreement between the other three figures indicates that the average ber of eggs per female to be expected is at least 7,000.

The minimum number of salmon eggs to be expected at Shasta Dam, based n 7,000 eggs as an average number per female, and a minimum of 10,000 female non reaching the dam, is 70,000,000 eggs for the fall run alone. The figure of 000 female salmon is obtained by assuming a one to one ratio of female to e fish in the migrating population. This was found to be the case when 805 e sampled during the 1938 fall migration. When it is assumed 70,000,000 eggs to be expected, the number of salmon in the spring and winter run, or the ber of steelhead in the winter run is not included in the estimate. The 1939 dies of the spring run will soon permit estimates of the fecundity of these h. The 5,600 spring salmon already counted this year would mean approximately 000,000 more eggs. In addition, there is the previously mentioned winter run consider. It is quite evident then, that the number of eggs to be expected l be around 100,000,000.

If about 100,000,000 eggs may be expected from the run which now goes past site of Shasta Dam, and if salvage operations are to depend upon artificial pagation alone, the number of eggs to be handled would be greater than that ich is now produced by all the federal salmon hatcheries.

Spawning areas were surveyed by a direct method of pacing along the bank. e survey of spawning grounds in the reservoir was completed before the begin ng of the fall run of salmon in 1938. This afforded an opportunity for examina on of a large part of the grounds while the fish were spawning and enabled a rtial check of utilization of areas which had been previously classed as spawn g riffles. In general, two conditions seemed inevitably to be required by awning salmon in their selection of type of bottom:

1) a diatomaceous covering of the gravel, and

2) a suitable mixture of sand and finer gravel which was compact enough to ghtly hold the aggregate together.

The diatomaceous covering is one indication of a relatively stable bottom. eas of the stream bottom where very little diatom growth was seen were always aces where rapid current or shifting bottom was caused by scouring action of ne current. Such places seemed to be avoided by spawning salmon. Likewise,

places in the stream bottom covered with grit, or fine sand or clay sediment, did not attract spawning salmon. Within the limits of the Shasta reservoir, there is a total linear distance of 100 miles, of which 3.5 per cent is considered suitable for spawning.

Several measurements were made by the surveyors of the number of square feet utilized by individual female salmon in making redds, or nests. The size of such uprooted sections varied from 3 by 5 feet to 9 by 10 feet, with an average area of approximately 40 square feet. Using this figure, it was established that there was spawning area for 85,000 adult salmon.

Surveys of areas above the lake formed by the dam have not been completed, but enough has been learned to indicate the approximate extent of the spawning grounds which will be destroyed. The number of miles of stream above the reservoir which is at present accessible to salmon and steelhead is roughly 112. Of the total area of stream, 2.75 per cent of the bottom is estimated to be available for spawning salmon.

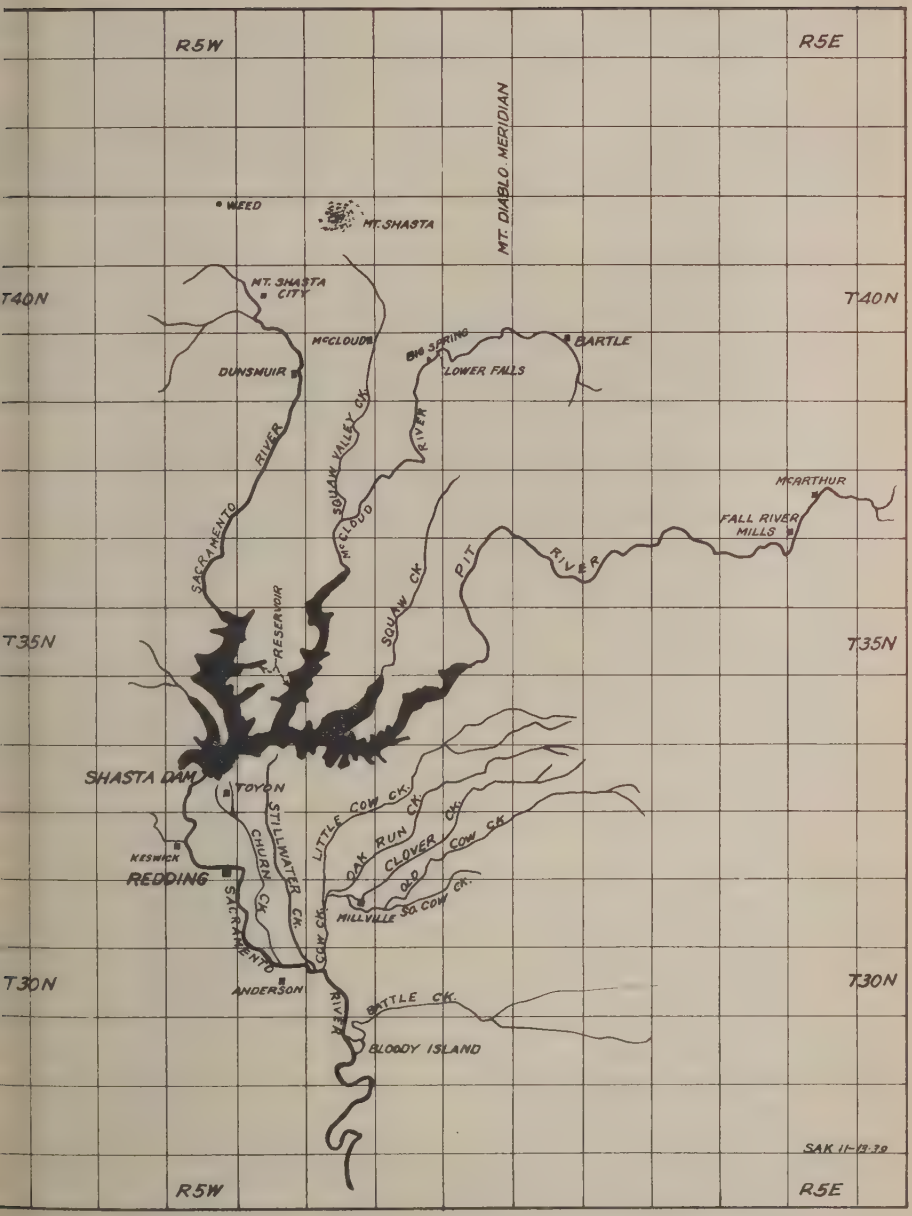
The problem of trapping the fish is the first one to be solved, because this will be necessary before anything can be done. The Anderson-Cottonwood Dam at Redding where counts are now being made, as noted previously, is a demountable structure and not at present suitable for trapping use. If it were used it would have to be taken over and remodeled. The alternative is to rack the Sacramento River with a permanent structure, capable of withstanding high water.

Having trapped the fish, the problem remains of what to do with them. The permanent flowing tributaries to the Sacramento below the Shasta Dam have all been examined except the Feather River, and so far none has been found to have sufficient available spawning area to provide for transferring the runs and relying on natural reproduction. With the possible exception of Battle Creek, no stream has been found below the dam which could be used for holding and ripening the green spring run. Experiments are being made now to find out if Battle Creek can be used to hold and ripen spring fish. There are several springs in the region that are large enough to supply large hatcheries, but all of them are at least 80 miles from where the adults must be trapped, and they are above Shasta Dam. If these were to be used to take care of the runs artificially, the adults would have to be hauled up and the young hauled back and planted below the dam.

The homing tendency of Pacific salmon to return as adults to the streams which they left when young will reduce the cost of salvage operations. If it is decided to attempt transference of the runs to other streams, below the dam site, this process should be necessary for only one cycle. After one cycle of trapping operations in the main river, operation of this unit of the salvage plan would be reduced to catching of normal strays and such steelhead as were not transferred in the first cycle of years.

It would be well to mention another possibility that may aid in the solution of the salvage problem. About 17 miles below Redding, Stillwater Creek enters the Sacramento River. This stream rises in the foothills that bound the southern edge of the future reservoir and flows south some 25 miles where it joins the Sacramento River. At present, it has intermittent flow and is dry over part of the summer and fall. Surveys showed king salmon to spawn in it naturally, and the bed over almost its entire length is a splendid natural spawning ground.

It has been proposed that water be brought either from the future Shasta reservoir itself or by flume from the upper McCloud River, through a tunnel to the headwaters of Stillwater Creek to furnish a permanent year-round flow to this stream. After a permanent water supply is available, all, or a portion, of the fish that now run past Shasta Dam might be transferred to this stream. Once



Upper Sacramento River. Shasta reservoir and vicinity.

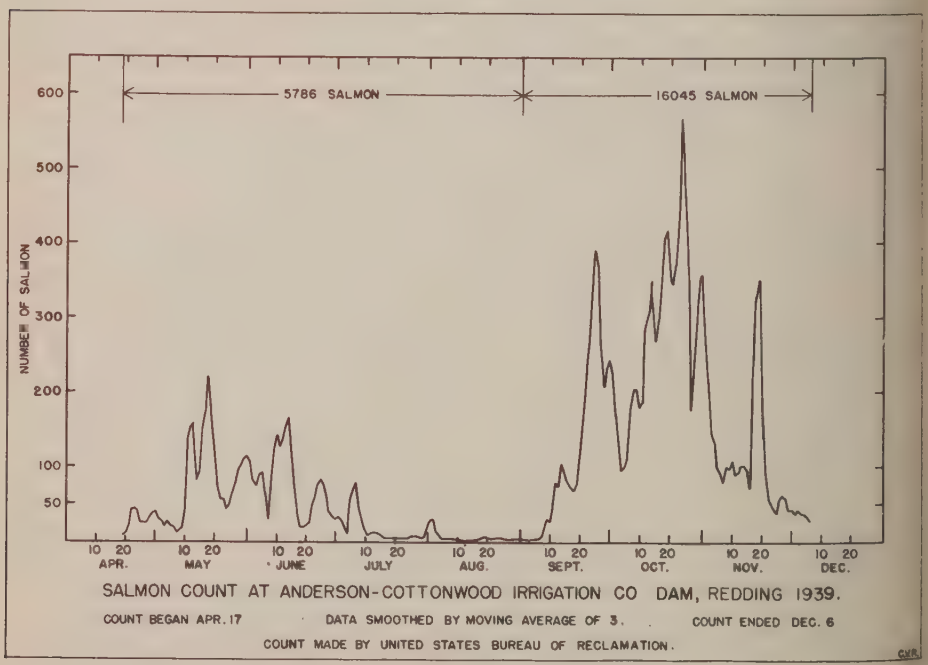
there, they could either be allowed to spawn naturally, if they would, or held and ripened and the eggs taken artificially and hatched in hatcheries.

This plan also presents another possibility: adult fish might migrate under their own power to the head of Stillwater Creek, through the tunnel and, if McCloud River water is flumed to Stillwater Creek, they might continue up the flume and into their normal spawning areas in the upper McCloud River. If they did this, it would be necessary to screen the upper McCloud at the point of diversion to turn the seaward migrants into the flume and to prevent them from passing on downstream into the Shasta reservoir.

Several modifications of the plan to use Stillwater Creek have been proposed. Engineering and biological investigations are in progress and only on the basis of the facts determined will it be possible to make a definite decision as to what special plan, or combination of plans, is the most likely to provide the solution of the salvage problem.

The fish are there; they must be protected; and with engineering and biological studies only about half completed, no complete plan can be presented now. As soon as all the facts are in, then, and then only, can definite decisions be made.

In summary, any plan proposed must be in accord with the habits and instincts of the fish concerned, and be practicable on a long-range economic, as well as a fish cultural basis, in order that the present run of migratory fishes in the upper Sacramento Basin may be preserved, or even enlarged, for the present as well as future generations.



A SUMMARY OF THE PRESENT STATUS OF DAMS VERSUS MIGRATORY FISHES ON THE PACIFIC COAST WITH ESPECIAL REFERENCE TO PROBLEMS IN CALIFORNIA

By A. C. Taft, Chief, Bureau of Fish Conservation,
California State Division of Fish and Game

The preceding papers have outlined in detail the nature of the problems sented by the construction of large scale dams for the utilization of water in West. They have also indicated the steps taken by engineers and fisheries logists to protect and conserve the runs of migratory fishes that were en- gered.

At Bonneville the primary problem was to provide for the passage of fish t the barrier formed by the dam and this was accomplished by providing ade- te fish ladders and fish locks. At the Grand Coulee Dam it has been decided t it is not feasible to provide means for the fish to pass the barrier and, as alternative, the runs that would normally pass above Grand Coulee are to be nsferred to lower tributaries through artificial propagation.

In the case of the Central Valleys Water Project here in California, on ch construction work is just starting, it has been indicated that the salvag- of the king salmon run will probably be similar to the methods used at Grand lee.

From the foregoing, it can be seen that the fisheries biologists have not irked their responsibilities, nor have they been over-awed by the magnitude of e problems presented. However, they have been handicapped in various ways in tempting to make the necessary adjustments for the protection of the fishes. e first question that arose was that of the economic value of the fishery in- rests involved. Few of the governmental or public agencies engaged in the con- ruction of the dams had any knowledge of the value or importance of the fishes a natural resource. As illustration of this, a board was appointed for the udy of our water resources and their utilization, on which there was not a ngle representative who was familiar with fisheries problems. The engineers in arge of the planning and construction of these large projects had been inter- ted in fish largely from their recreational use and were not particularly im- essed with the necessity for considering the importance of the fisheries re- urces.

It was difficult to overcome this type of inertia due to the fact that we re not fully prepared ourselves to evaluate the social and economic importance our fisheries resources. Fairly complete statistical records were available r the commercial species involved, and the dollars-and-cents value of the catch uld be calculated, but the potential value of a biological resource cannot be tisfactorily determined entirely in that way. It is probable that a resource ch as the salmon of our western river systems could never be restored, once estroyed. In any event, it could only be restored at a much greater cost than ould be required for the construction of fish ladders and screens or the pro- sion of new spawning grounds for existing runs of fish.

All fishery workers probably realize that water here in the West is bound be utilized to an increasing extent; they should, therefore, be prepared to valuate the fisheries resources involved and to bring them forcefully to public ttention.

The determination of recreational value of fishes is even more difficult han in the case of the commercial species. We have here in California some 30,000 people who take out angling licenses, and it has been estimated that hey, together with the hunters, spend $80,000,000 per year on those types of

recreation; but the social value of the recreation itself cannot be measured at all.

The second great handicap for fisheries workers in their work derives in part from the lack of recognition of their problems, that has been outlined in the foregoing. In all too many instances, they have not been consulted until the plans for the proposed construction were completed and actual work about to begin. After that there were often delays in providing funds for their work and, in some instances, no provision was made for the study of the fishery problems until construction was actually under way. In such cases, minor adjustments that might have been made with relatively little cost and with large benefits to fish, became impossible. An outstanding example of this type is found in the debris dam recently constructed on the North Fork of the American River, California, by the U. S. Army Engineers. Now a debris dam is a new type of barrier for fisheries biologists to deal with. Briefly, its purpose is to impound the gravel and silt from hydraulic mining in order to prevent them from damaging agricultural interests using the water below, and to prevent the clogging of navigable river channels. As has been said, they presented an entirely new potential danger to fishes. There were questions not only of the effects on migratory fishes, but also on the types native to the streams above that were to become sluiceways for thousands of tons of debris. In spite of the importance of the matter, the Bureau of Fisheries was not called into consultation until shortly before the bids were let for the construction. The dam is now in operation, hydraulic mining is in progress, but the U. S. Army Engineers have not yet been able to make public the report of the Bureau as to the probable effects of the dam on fish life.

It might be well to review at this time the present provisions of the law, both state and federal, under which we now work. It will not be possible to review the laws of all of the eleven western states, but it will probably suffice to take California as offering a typical illustration of the general existing legal machinery with which the fisheries administrator works. California has had laws requiring the construction of fishways since 1895. Avoiding technicalities as much as possible, the present California laws may be summarized as follows:

1. The Division of Fish and Game receives a copy of each application that is made to the Department of Public Works for the construction of a dam.
2. Within ten days after filing, a hearing must be held, if the Division believes that a ladder is needed.
3. If, after the hearing is held, the Division believes that a fishway is necessary and practicable, the owner is notified and thereafter it is unlawful to begin construction until the Division has approved the plans for the required fishway.
4. The owner of a dam must provide for the passage through the fishway or around or through the dam of sufficient water to keep in good condition any fish that may be planted or exist below the dam.
5. If a fishway is not practicable, the Division may require the construction of a hatchery with its attendant facilities, which is thereafter operated at the expense of the Division.
6. The Division may require the screening of all flumes and conduits under a complicated procedure, which, suffice it to say, is not entirely satisfactory.

We now have in California 1,300 dams exceeding 15 feet in height. At 163 of these, fishways have been constructed that are reasonably effective, although I believe it may safely be said that at none of them are conditions as satisfac-

as before the dam was constructed. It may appear that, with fishways con-
ucted on only 12 per cent of existing dams, conditions are far from satis-
tory. Such is not a true picture, for in many instances fishways are obvious-
not required. Probably in not over 20 per cent of the cases could fishways
e reasonably been required, and even then, there would have remained many
tances of reasonable doubt. In only two cases has the Division required the
struction of hatcheries in lieu of fishways, and in both, large power dams
e involved.

It is my view that our present state laws are reasonably satisfactory.
re is considerable improvement needed in our present screen law, and in addi-
n to that, there should be definite provision made for agreements covering the
and flow of water. Although the present law requires that a satisfactory
unt of water must be allowed to flow below the dam, it would be much better
probably more easily arranged if this were specified at the time the dam was
structed and made a part of the fish ladder requirements. Many adjustments and
erstandings could be made at that time that would be of definite benefit to
fish and of little inconvenience to the operators of the dam.

Only since 1934 has there been any federal provision for fish protection
connection with the construction of dams by agencies of the U. S. Government,
under permit. The law is very brief and reads as follows:

of March 10, 1934, Chapter 55, U. S. Statute, Section 3, Article B,

"Hereafter, whenever any dam is authorized to be constructed, either by
Federal Government itself, or by any private agency under Government permit,
Bureau of Fisheries shall be consulted, and before any such construction is
un or permit granted, when deemed necessary, due and adequate provision, if
nomically practicable, shall be made for the migration of fish life from the
er to the lower and from the lower to the upper waters of said dam, by means
fish lifts, ladders or other devices."

This statute, in effect, provides that the U. S. Bureau of Fisheries is to
called in as a consultant by any agency contemplating the construction of a
n under federal supervision. This was a somewhat belated step in the right
rection but has not been entirely satisfactory in operation. In certain in-
ances, the Bureau has not been called upon at all or only after plans were
npleted and construction actually under way. They were then dependent upon the
nstructing agencies for the funds to carry on this work. After their investiga-
on and study was completed, it was entirely optional with the agencies con-
rned to accept or ignore their recommendations.

As a program for future action, I would recommend the following:

1. That fisheries biologists and administrators be prepared to evaluate
e resources under their supervision and that they bring the information thus
rived to public attention.

2. That the various state departments on one hand and the Bureau of Fish-
ies on the other, accept responsibility for the protection of fisheries re-
urces legally under their supervision. Although the federal projects are more
ectacular in size, numerically the job of the states is much the greater. No
ngle national agency could hope to cope with them. There is not a single stream
California on which federal projects are contemplated where dams do not al-
ady exist which cannot be brought under federal control, and a coordinated, co-
erative effort will thus be needed. A strengthening of legal authority will be
quired for some states and for the Bureau of Fisheries. The latter should have

funds and the authority to determine the practicable fisheries requirements, and should then be expected to accept responsibility for seeing that they are put into effect.

3. We should be more insistent that ample time be given for the formulation of plans for fish protection and that in general they be agreed upon before construction starts.

4. That such agreements include, specifically, provisions for the flow and water levels to be maintained, and that they be made with the view that the fisheries should at least be given consideration in proportion to their demonstrated present and future value.

DISCUSSION

CHAIRMAN (Dr. F. B. Sumner): I think in view of the remarks of the last speak- that perhaps the discussion had best be started by a resolution which Dr. s wants to present.

DR. G. S. MYERS: This resolution as drawn up may not entirely cover the situ- n, but at least covers part of it. (Reads resolution.) (See page 213.) I move this resolution be adopted. (Seconded by Dr. P. R. Needham.)

CHAIRMAN: Is there any discussion before we put this to a vote? There are pponents, apparently. All in favor will please respond by the usual sign. s.) Carried unanimously. Will you put that in the minutes, Madam Secretary? , in the ensuing discussion, I will request that each one of you who partici- es will give his or her name, because stenographers are taking down the re- ks of the volunteer speakers for inclusion in our report of the symposium.

MR. LEO SHAPOVALOV: When we speak of the consideration of the requirements of iculture and power development, and the consequent need or lack of need of se dams, we should keep in mind the fact that such requirements are not abso- e things, but are relative to our general social and economic conditions. The ter, in turn, must be considered to be in an abnormal state of development at present time, in relation to the normal development of our natural resources civilization generally. Evidence of abnormal conditions lies in the facts t the birth rate is declining in many countries, and that we are likely to h a stationary or even declining population in this country, whereas, at the e time, some agronomists tell us that, from the viewpoint of space and agri- tural production, the earth's surface can probably support double its present ulation. Unemployment relief and armaments are also phenomena which cannot be sidered a part of our natural development. Now, the construction of these dams connected directly with the existence of these abnormal conditions; many of dams are being built *principally* to alleviate unemployment, and others are ng built in connection with industrial development associated with the pro- tion of armaments and war materials. Finally, in many cases, the power de- oped at these dams is being used for the benefit and interests of compara- ely small groups. Therefore, it behooves biologists to think, not only in ns of biology, but also as citizens of the community and the country, and to dy the basic social and economic conditions upon which the construction of se dams is dependent. If biologists attempt to divorce biological problems n social and economic considerations, they are likely to become simply tech- ians, even if very good technicians.

CHAIRMAN: Mr. Shapovalov's remarks certainly deserve a place in our records.

DR. L. E. GRIFFIN: I would like to call attention to a fact that has become arent since I became interested in the question of the Bonneville Dam: that bad situation of the migratory fishes in Oregon and Washington is not now, is not going to be, wholly the fault of the dams. In the Columbia River the ch of salmon has fallen off about 50 per cent during the last 20 years. During ent years it has amounted to about two million fish a year. Last year, only ut one-tenth as many fish as were caught got into the upper Columbia River to wn. The number which passed through the Bonneville Dam fish ladders was twice t many, but the number was considerably reduced by commercial fishing in the t 60 miles. Presumably, a considerable part of the salmon which escape the mercial fishermen spawn above Bonneville, because the conditions for spawning

in the lower river are not as favorable as in the upper river. It seems to me that the number of fish which may reach the spawning grounds is so small in comparison with the total number of those caught, that a quick and certain reduction in the fisheries of the Columbia River will take place because of the commercial fishing rather than because of Bonneville Dam. I have little sympathy with the construction of dams across the Columbia River; nevertheless, I feel that we may ascribe more blame to Bonneville Dam for the reduction of future salmon runs than may be due it.

A question I should like to ask of Dr. Rich is: what information can really be gotten in regard to the migration of young fish by these marked fish? I think the records of previous experiments show that about one fish out of each 1,000 has been recovered, and that would mean that, if 100,000 are marked, we can hope for only 100 fish to be captured out of the 100,000. I would like some information as to the probable statistical value of the marking experiment.

Dr. W. H. RICH: Well, if we don't get enough returns, we won't know; but if we get any returns at all, we will be able to determine statistically the probabilities involved, and the indications that a dam does or does not have a material effect on mortality of the downstream migrants. The experiments were designed specifically to test just that one thing. Does that answer the question?

DR. GRIFFIN: In the group experiments to which I referred, about one fish in 1,000 marked has been recovered. One hundred thousand of your fishes are marked. One hundred will be recovered. Will that give a basis for statistical conclusions?

DR. RICH: Yes. I can say very definitely that we can state our conclusions, in terms of probabilities, by applying the statistical methods proper to such problems. If we only got 50 back, our conclusions could still be stated in terms of probabilities. It may be that these probabilities will not be satisfactory—in other words, that the results of the experiment will not be conclusive—but that will depend upon the degree of difference we observe in the returns from fishes planted above and below the dam. If we get only a dozen back, we can determine the probability of such difference as is observed having occurred purely by chance; and the experiment has been carefully planned so that, if the observed differences cannot be ascribed to chance, we can safely assume that there has been a differential mortality. We shall be able to state just how probable it is that the dam does or does not affect the death rate during the seaward migration on the basis of the returns, regardless of how many returns we get. But, of course, the more returns we get, the more valuable will be the determinations.

MR. THOMAS LARGE: There is one thing in my experience of trying to get the plight of the Pacific salmon over to the public. Laymen do not discriminate between facts of the life history of the Atlantic and Pacific species. The biologists in general know the natural history of the salmon well enough to know that the Columbia River salmon spawns but once. The public does not know that, and the popular literature is full of salmon stories concerning the salmon of the Atlantic, and the facts given are assumed to be true for the Pacific salmon.

CHAIRMAN: Dr. Fraser is with us. Do you not have something to add to this discussion?

DR. C. McLEAN FRASER: Mr. Chairman, it is some time since I did much work on Pacific salmon, but I have not lost interest in the investigation as it continues. Every encouragement should be given to those men who are trying to find ways and means to minimize the possibility of the destruction of the salmon runs up the various rivers and streams that are undergoing such extensive changes due

he power and irrigation projects, for here there is a real menace. It is e possible, though, that much of the outcry against the companies that are onsible for the development of these projects has been introduced to cover up fact that much, if not most, of the depletion is due to overfishing.

As to Dr. Griffin's suggestion that a return of one marked fish in 1,000 be of no statistical value, I am afraid that I cannot agree. In any case, higher returns than this have been obtained. If I remember rightly, Dr. ster, in his sockeye salmon experiments in Cultus Lake, B. C., got as high hree per cent.

DR. RICH: It is quite true that Dr. Foerster's experiments showed a much er return, but it is also true that practically all experiments with salmon hat species have shown much higher returns than have the general run of riments with the chinook salmon. But these experiments we are conducting at eville have to do with the chinook salmon.

DR. W. M. CHAPMAN: I would like to add a bit of information to substantiate Griffin's remarks on overfishing. I have just recently been working on the istics of the Columbia River fisheries. Using the fish counts at Bonneville and the statistics of our commercial fisheries on both the Oregon and Wash-on sides of the river, it is apparent (I think Dr. Rich will back me up, at st roughly, on this point) that the fishing mortality in the spring chinook s in excess of 80 per cent. In other words, of every ten fish entering the er, eight are removed by the fishery. The sockeye salmon fishery shows ap-ximately the same fishing mortality as the spring chinook. The situation is ferent in regard to the fall chinook runs and the steelhead, where, apparent-not more than 50, or at the most, 60 per cent of the fish are removed by the mercial fishery. In studying the statistics of past years, we find that the ld of the sockeye and spring chinook runs has greatly increased. This is not e, however, of the fall chinook runs or the steelhead. There is a differential ing mortality on the different runs which should be taken into consideration. different runs are subjected to different conditions, and the group cannot be ated as a unit.

DR. RICH: I would like to support Dr. Chapman's statement, and also to point that, even in the spring run, there is a distinct differential between the in the early part of May, and in June or July. The fishing mortality early in is much lower than in June or July. Judging from the result of a study of the of 1938, the fishing mortality during June and July, when the run is rela-ely small, is even higher than has been indicated by Dr. Chapman. Apparently, ing these two months, the ratio of catch to escapement was approximately seven one.

DR. CHAPMAN: I would like to remark that these spring and summer fish are of ne quality, whereas the fall chinook, which are not decreasing so rapidly, are poorer quality. Pound for pound, the fisherman gets from four to six times as n for the spring and summer fish as for the fall fish. Naturally, he likes to ch the high-priced fish. What is happening is that we are killing off the h-priced fish, and giving the low-priced fish adequate protection.

This has been a remarkably friendly symposium. I think it might be well to roduce a discordant note. The point Mr. Taft brought out in his talk has given great concern in our state. We have our laws. They fortunately place us in a ition to demand privately owned utilities and private users of water in our te to incorporate in their structures adequate protective devices for fish at ir expense. And I might say that, entirely aside from the legal force which we

could exert, the large users (such as the Puget Sound Power and Light Co., a the Northwestern Electric Co.) have in recent years been extremely cooperati where they could have been really nasty and still been within their legal right

The situation as regards the various divisions of the federal governme and municipal governments is quite to the contrary. We have no methods of leg persuasion, and in many cases cooperation has been very difficult to obtai Having no legal weapons, we are continually forced to stir up public opini throughout the state, in order to get both the federal and municipal agencies give fish proper protection at their dams, etc. I wish to bring out this poi strongly: the industrial and agricultural use of water is passing more and mo to federal or municipally owned agencies. These agencies are outside the law regards fish protection, and are in many cases extremely high-handed in the treatment of fisheries problems. Some method should be devised to force them give the same consideration to fish protection that is demanded from priva users of water.

CHAIRMAN: One question I would like to ask, Dr. Chapman. To what extent ha pressure been brought by agricultural interests in the Northwest to develop th Grand Coulee Dam? Has there been any serious call by agricultural interests, o has the initiative been taken by the government?

DR. CHAPMAN: Well, Eastern Washington people are nearly as rabid on the Gra Coulee project as the people of California are on the climate. The Central Wash ington people have been advocating such a project for a long period of years with no hope of getting it. Then the administration gave it to them, and they a naturally very grateful for it. The adverse comments concerning the Grand Coul project which you read in national journals do not come from the State of Wash ington.

CHAIRMAN: Then it is in response to a real demand?

DR. CHAPMAN: Yes. And you can very well understand it if you saw the tremen dous area of fertile soil to be brought into cultivation. The agricultural a well as the hydro-electric possibilities are tremendous. I should not like t leave the opinion that our organization is opposed to the Grand Coulee project Our business is to protect the fisheries of the state. We believe that it i possible to develop the industrial, agricultural, and fisheries use of our water side by side, without the elimination of the latter.

MR. H. B. HOLMES: Mr. Chairman, Dr. Chapman has brought to a point an attitud that has been the undercurrent of this entire meeting: that is, a lack of inter est, on the part of other water users, in giving adequate consideration to th requirements of fish. Dr. Chapman, in his final comment, also expresses an atti tude on his part, which I believe may explain the attitude of other water user toward fish. Dr. Chapman recognizes the public interest in irrigation projects and the value of lands to be put to use, but he, himself, will leave the promo tion of such projects to others. This is a human attitude, and one that we shoul expect to find paralleled in the minds of the other water users. Our business i fish. We are not going out of our way to look for opportunities for other wate users. Should we expect the other water users to go out of their way to see tha their interests do not conflict with ours?

I wonder what is the solution to this perfectly human difference? As Mr Taft pointed out, one solution is through legal processes. We should have law that will require these other water interests to give adequate consideration t fish. However, we should not expect organizations such as the United State Engineers and the Reclamation Service to step out of their way in the conserva-

ion of fish. We must remember that they are under the pressure of those interests, for whom, we might say, they are working. They might actually be willing to e forced into adequate fish protection, but could not be expected to respond ithout a balance of sentiment in its favor. Even the most ideal laws can not ompletely correct this situation.

It is pleasing to find that there is a decided increase in public interest n conservation, in this case, in fish conservation. In that direction I think we ay find our greatest hope. If we can further increase this public interest, and btain the power of the public as backing, I think *there* is our greatest chance or success.

CHAIRMAN: Is there a motion to adjourn? (Moved and seconded.) The meeting is djourned.

AMERICAN SOCIETY OF ICHTHYOLOGISTS AND HERPETOLOGISTS

WESTERN DIVISION
MARGARET STOREY, Secretary
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Stanford University, Calif., U. S. A.

PUBLISHERS OF "COPEIA"

RESOLUTION

The Western Division of the American Society of Ichthyologists and Herpetologists and the Western Society of Naturalists, being assembled at Stanford University, California, at this Annual Meeting and having considered in considerable detail the effects of dam construction in west coast waters and their incident and usually harmful effect on migratory fishes such as salmon and steelhead trout, hereby offer the following resolution to be presented to the various federal and state agencies, National Resources Committee, Western States Planning Boards, Water Resources Committees, and other bodies concerned with water planning programs:

WHEREAS construction of the Bonneville and Grand Coulee Dams on the Columbia River in Oregon and Washington, the Shasta Dam on the upper Sacramento River in California, and other such federal and state projects has, and will continue to, greatly jeopardize the continued productivity of salmon and steelhead trout to the people of west coast states, and

WHEREAS actual construction work on each of these dams has, almost without exception, been begun without sufficient advance consideration of the effects of the proposed structures on salmon and trout, therefore

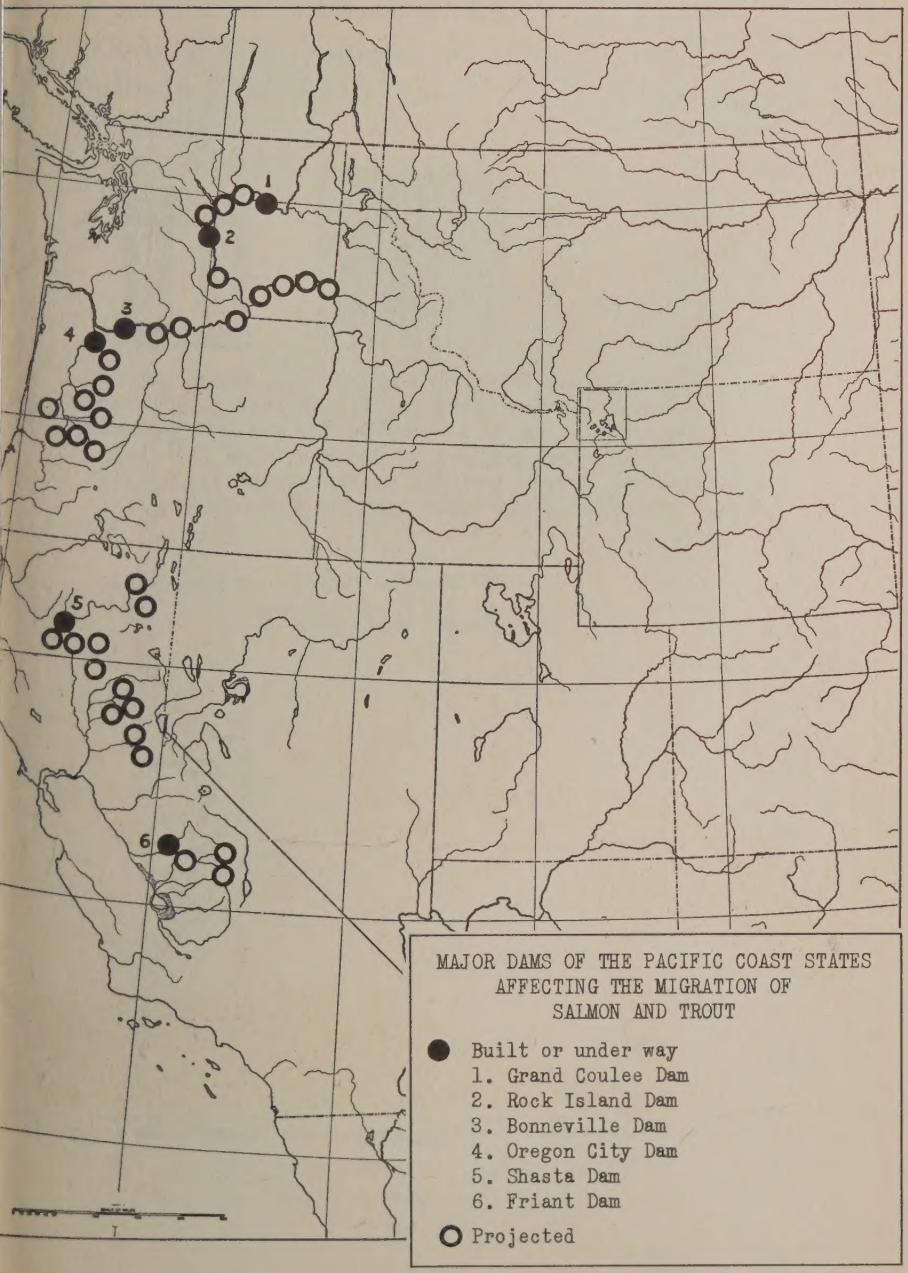
BE IT RESOLVED: that fisheries resources be given consideration equivalent to that given all other water uses by federal and state planning or construction agencies and that before starting construction of any dam or other type of structure proposed in any basin containing salmon or steelhead trout, surveys of the fisheries resources be made by qualified experts, to parallel engineering surveys, over a minimum period of five years, or sufficient to cover the life cycles of all economically important fishes concerned.

Margaret Storey

Margaret Storey, Secretary
Western Division, American Society of
Ichthyologists and Herpetologists

June 29, 1939

COLUMBIA BASIN
SCALE IN MILES
10 0 10 20 30 40
OSOYOOS LAKE
OKANOGAN RIVER
METHOW RIVER
SANPOIL RIVER
CLARK FORK
RIVER
SPOKANE
SPOKANE
GRAND COULEE DAM
ROCK ISLAND DAM
WENATCHEE
LEAVENWORTH
ENTIAT RIVER
LAKE CHELAN
WENATCHEE
NACHES RIVER
YAKIMA RIVER
YAKIMA
YAKIMA
SNAKE RIVER
WALLA WALLA RIVER
UMATILLA RIVER
COLUMBIA RIVER
JOHN DAY
DESCHUTES R.
CELILO FALLS
SKAGIT RIVER
SKYKOMISH RIVER
SEATTLE
WHITE RIVER
MISQUALLY RIVER
CHEHALIS RIVER
COWLITZ RIVER
LEWIS RIVER
LEWIS RIVER DAM
BONNEVILLE DAM
VANCOUVER
PORTLAND
WILLAMETTE R.
OREGON CITY
WASHINGTON
OREGON
N


1
2
3
4
5
6
MAJOR DAMS OF THE PACIFIC COAST STATES
AFFECTING THE MIGRATION OF
SALMON AND TROUT
Built or under way
1. Grand Coulee Dam
2. Rock Island Dam
3. Bonneville Dam
4. Oregon City Dam
5. Shasta Dam
6. Friant Dam
Projected

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